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Assessment of the Run to Detonation in Composition B from M732 Fuze Booster Assembly

M. Chick and L. McVay

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Abstract

We report on laboratory tests to assess the build-up to detonation in the Composition B filling of the 105 mm shell from the booster assembly of a M732 short intrusion fuze. These tests were undertaken because the M732 fuze is to replace some types of long intrusion fuzes in Australian production 105 mm HOW HE M1 shell.

Conclusions from this limited investigation are: (a) the delay in the build-up to detonation is small but significant, (b) an increased gap of 2 mm caused by the addition of extra glazed board packing between the M732 booster and the Composition B filling substantially increases the build-up delay to a point where it may approach the detonation failure threshold, and (c) consideration should be given to a more detailed investigation to assess the effect of likely combinations of glazed boards, felt pad and air gaps on the build-up process.

MATERIALS RESEARCH LABORATORY

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1. Introduction

The short intrusion fuze, M732, is being incorporated into Australian production of shallow cavity 105 mm HOW HE M1 shell. The M732 will replace current long intrusion type fuzes (e.g. M728). This decision was based on cost savings through deletion of the requirement to drill out the filling for the long intrusion fuze and because a long intrusion proximity fuze can no longer be procured. DAP-A requested the Australian Ordnance Council to verify that the M732 was safe and suitable for service. Inspection of the shell and initiation systems of the two types of fuze designs shows that although the M732 booster explosive, CH-6, is more powerful (i.e. higher detonation pressure) than the TNT booster (also termed the supplementary charge) in the long intrusion fuzes there is a considerably smaller quantity of explosive present. Furthermore, the M732 booster does not protrude into the main explosive filling. Therefore initiation is produced by the shock generated from the front face of the booster after traversing the inert packing at the base of the fuze. The deep penetration of the supplementary booster charge of the long intrusion fuze into the main explosive filling, however, suggests that initiation can occur from the shock passing through the side wall of the cavity as well as from that generated from the booster's front face.

As a consequence of the above considerations DAP-A tasked MRL [1] to undertake a laboratory assessment of the build-up to detonation characteristics in the Composition B filling of the 105 mm HOW HE M1 round from the M732 booster assembly. This report presents the results of the investigation.

2. Experimental

2.1 Method

The test set-up shown in Figure 1 was designed to simulate the immediate environment surrounding the M732 fuze booster and top section of the Composition B filling in the 105 mm shell shown in Figure 2. Reference to Figure 2 shows that the CH-6 booster pellet does not protrude into the Composition B filling. Thus initiation will be from the shock generated from the front surface of the pellet after traversing the inert packing.

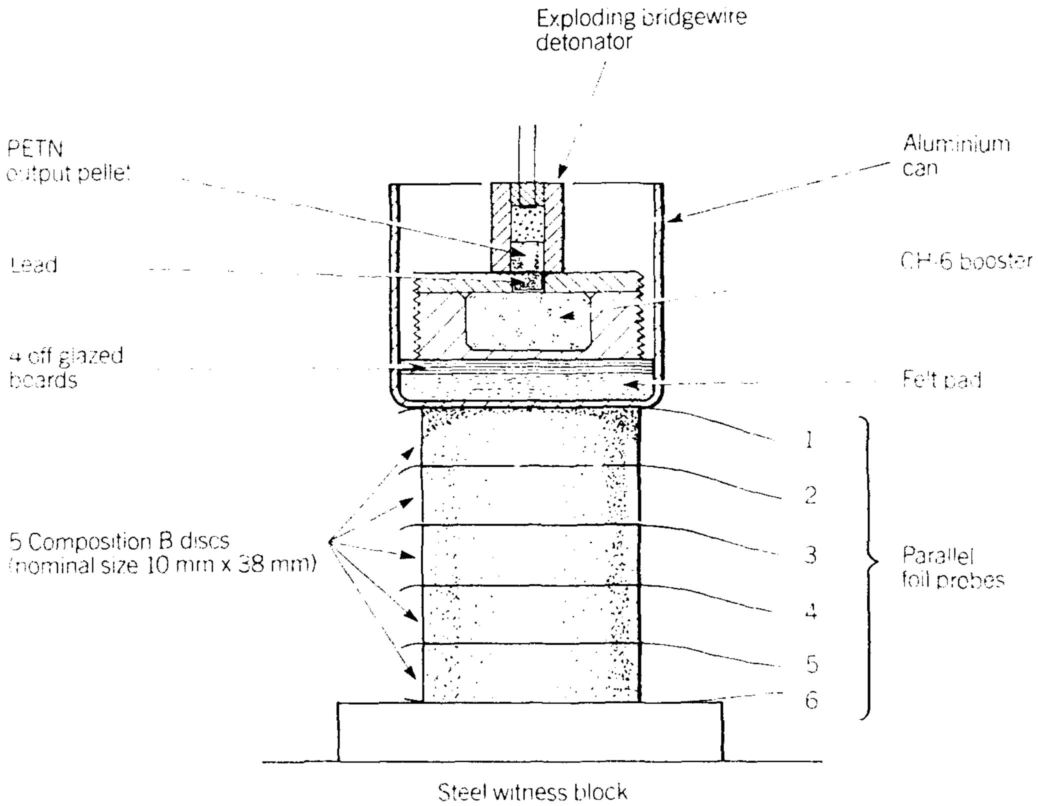

Figure 1: Sketch of assembly to measure build-up to detonation in Composition B from Shallow Intrusion Fuze M732 Booster Assembly.

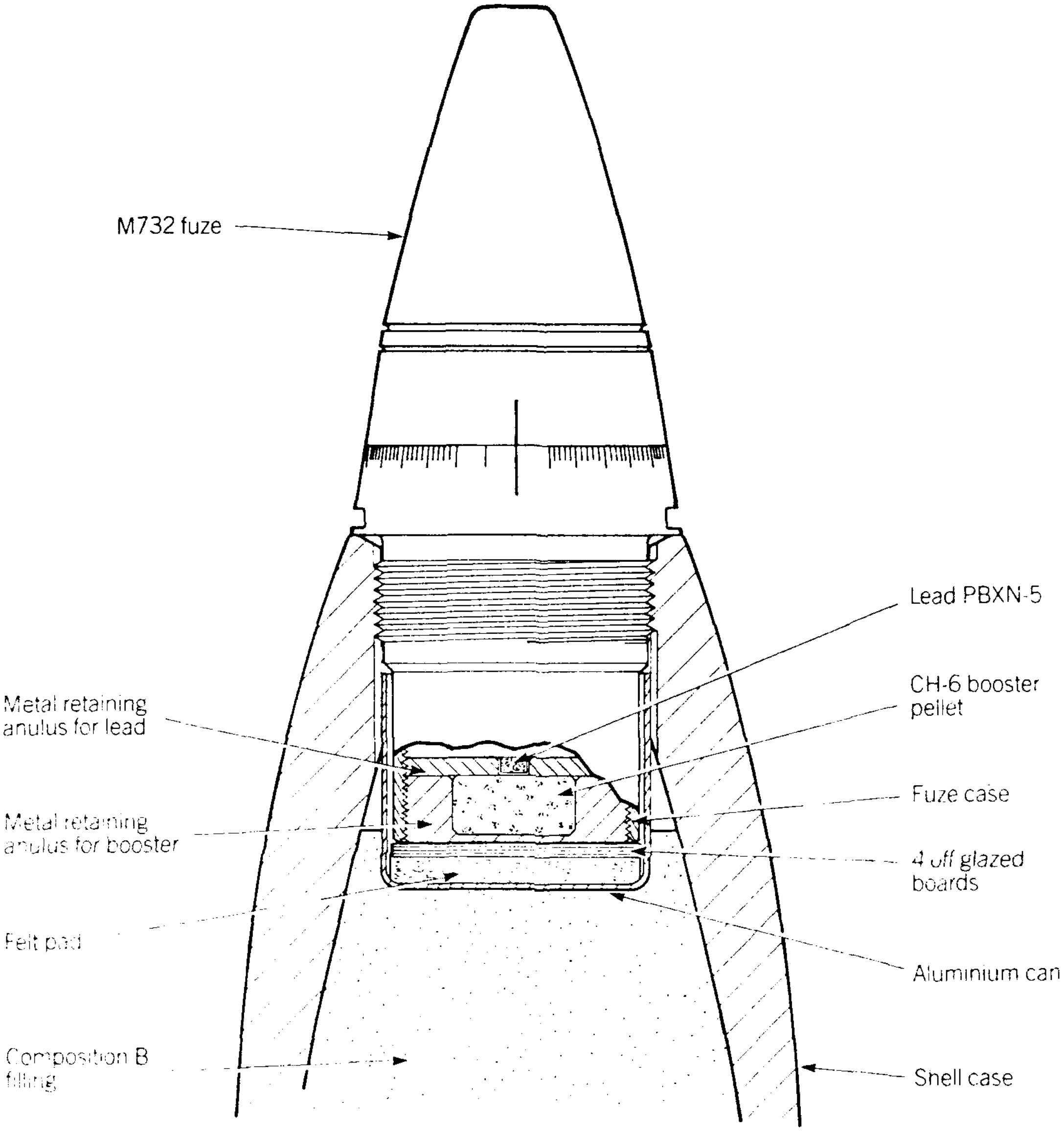

Figure 2: Sketch of Shallow Intrusion Fuze M732 located in 105 mm HOW HE M1 Shell.

The build-up to detonation measurements were made by incorporating time of arrival probes in the column of Composition B pellets. Each parallel foil probe consisted of a pair of 0.05 mm thick brass foils which acted as a switch in a capacitor discharge circuit. The first and last probes in the assembly were insulated from the aluminium can and steel witness block respectively by a thin layer of plastic. Ionization associated with the detonation front closed the switch and the resultant pulse was recorded and processed by high speed digital instrumentation with dedicated software developed by Explosives Division, MRL [2]. A dent with sharp edges in the mild steel witness block confirmed that detonation had been

established. The space/time plots produced were used to determine the time and run distance to detonation and the lost time due to the build-up process.

The Exploding Bridgewire Detonator (EBW) was selected for its availability, reliability of functioning, performance, safety and similarity in diameter of the PETN output pellet, 5.8 mm, to the diameter of the fuze lead, 4.9 mm. The fuze components were obtained by dismantling five fuzes. Both the lead and booster pellets remained in their annular metal housing. Details of the CH-6 booster are given in Table 1. The lead is 3.4 mm thick and consists of PBXN-5 (95% HMX, 5% Viton A). The aluminium booster can, glazed board and felt pad were arranged as shown in Figures 1 and 2. Relevant dimensions of these components are: aluminium can, 48.3 mm outside diameter, 34.5 mm high with a 0.5 mm base thickness; glazed board, 44.5 mm diameter and 0.5 mm thick; felt pad, 44.5 mm diameter and 3.2 mm thick.

Table 1: *Characteristics of CH-6 and TNT Supplementary Booster Charges*

Explosive and Fabrication Method	Composition	Dimensions mm	Mass g	Density Mg/m^3	Detonation* Pressure GPa
CH-6 Pressed	97.5% RDX, 1.5% Calcium stearate, 0.5% graphite, 0.5% Polyisobutylene	22.0 diam by 9.60	5.85	1.62-1.67	33
TNT Pressed Flake	98.5% TNT, 1.5% Barium stearate	43.4 diam by 63.2	136	1.45	17

* Calculated using the Becker-Kistiakowsky-Wilson (BKW) Computer Code.

The diameter of the Composition B column was significantly larger than the CH-6 booster (i.e. 38 mm vs 22 mm) and was therefore considered sufficient to simulate the confinement provided by the shell filling and case on the shock initiation process. The length of the column was selected to be greater than the estimated run to detonation distance (see Section 3).

The explosive filling in the 105 mm HOW HE M1 shell is Composition B made from Grade 1 RDX and this was the material used in the tests. It should be noted that this type of Composition B is significantly less shock sensitive than Composition B made from Grade 1B RDX. This is demonstrated in Table 2 where shock sensitivity values for the two types of Composition B obtained on the MRL Small Scale Gap Test (SSGT) are compared. The gap test value is the thickness of a brass gap that is placed between a standard donor charge and the test explosive that produces detonations in 50% of trials. The SSGT is described in detail in Reference 3 from which the data in Table 2 was extracted.

Table 2: MRL Small Scale Gap Test Data (see Reference 3)

Type of Composition B			Shock Sensitivity
Composition %	Type of RDX	Density Mg/m^3	Small Scale Gap Test Scale 2 Donor $M_{50\%}$, mm
RDX/TNT/Beeswax, 55/45/1	Recrystallized Grade 1A	1.704	0.42
RDX/TNT/Beeswax, 55/45/1	Boiled and Milled Grade 1B	1.696	0.87
RDX/TNT/Beeswax, 60/40/1	Recrystallized Grade 1A	1.708	0.50
RDX/TNT/Beeswax, 60/40/1	Boiled and Milled Grade 1B	1.704	1.03

2.2 Results

Five tests were carried out and all main charges detonated. Of these, three shots used the assembly shown in Figure 1, one shot used the CH-6 booster placed in contact with the Composition B main charge (i.e. the four glazed boards, felt pad and aluminium can shown in Figure 1 were removed) and in the other shot the number of glazed boards was increased to eight.

The detailed results from the five firings are listed in Table 3 and the space/time plots are shown in Figure 3. Times and distances are relative to the first probe. The run to detonation distance, x_r, the time to detonation, t_r, and the lost time, t_ℓ, were used to assess the delay in the build-up process and the estimated values are given in Table 4. The derivation of these parameters is illustrated in Figure 4, which shows a typical space/time plot of the shock initiation of a solid explosive. The run and time to detonation values were estimated from scaled up versions of the space/time plots in Figure 3. The steady state detonation velocities in Table 4 were calculated from a least squares fit of the data given in Table 3 where steady state detonation had been established. The mean velocity of detonation for shots 1 to 4 was 7.54 km/s; the low value from shot 5 was not included since steady state detonation may not have been achieved. It was considered that the small sample size precluded statistical analysis of any other data from the five tests. The lost time was calculated by subtracting the time for steady state detonation to traverse the Composition B sample from the time measured between shock entry and detonation exit of the sample, i.e. refer to Figure 4,

$$t_\ell = t - x/D \qquad (1)$$

where t is the time for the shock/detonation to traverse the Composition B column, d is the length of the Composition B column and D is the steady state detonation velocity.

Table 3: Distance/Time Measurements for Build-up in Composition B

Experiment		Probe Position Data											
		1		2		3		4		5		6	
Shot No.	Test Set-Up	Total Dist. x mm	Total Time t* µs	Total Dist. x mm	Total Time t µs	Total Dist. x mm	Total Time t µs	Total Dist. x mm	Total Time t µs	Total Dist. x mm	Total Time t µs	Total Dist. x mm	Total Time t µs
1	As Figure 1	0	0	10.1	2.3	20.2	3.7	30.3	5.0	40.5	6.4	50.6	7.7
2	As Figure 1	0	0	10.2	2.4	20.3	3.7	30.4	5.1	40.5	6.4	50.6	7.7
3	As Figure 1	0	0	10.2	2.6	20.4	3.9	30.5	5.3	40.6	6.6	50.8	7.9
4	CH-6 Booster in contact with Composition B, i.e. glazed boards, felt pad and aluminium can removed from assembly in Figure 1	0	0	10.2	1.7	20.4	3.0	30.5	4.3	40.7	5.7	50.7	7.0
5	Number of glazed boards in Figure 1 increased to eight	0	0	10.1	no record	20.3	5.5	30.4	7.6	40.5	9.1	50.6	10.5

* Note A zero reading indicates that a probe reading was obtained

Table 4: Detonation Build-up Characteristics in Composition B from Shallow Intrusion Fuze Booster Assembly

Experiment Shot No.	Estimated Run to Detonation Distance x_r mm	Estimated Run to Detonation Time t_r µs	Lost Time t_l µs	Steady State Velocity of Detonation D km/s
1	7	2	1.0	7.47 [Probes 3-6]
2	7	2	1.0	7.55 [Probes 3-6]
3	10	3	1.2	7.56 [Probes 3-6]
4	3	0.7	0.3	7.57 [Probes 2-6]
5	32	8	3.8	7.32 [Probes 5-6]

Note: Mean values for shots 1 to 3; x_r = 7.7 mm, t_r = 2.0 µs and t_l = 1.1 µs.

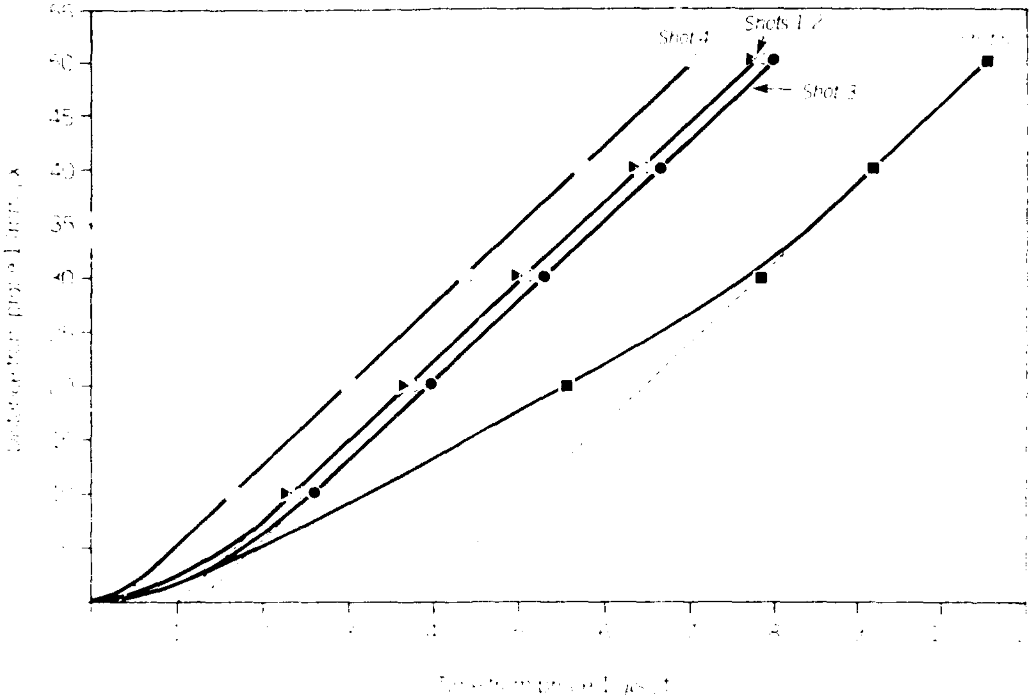

Figure 3: Space/time plots of run to detonation in Composition B.

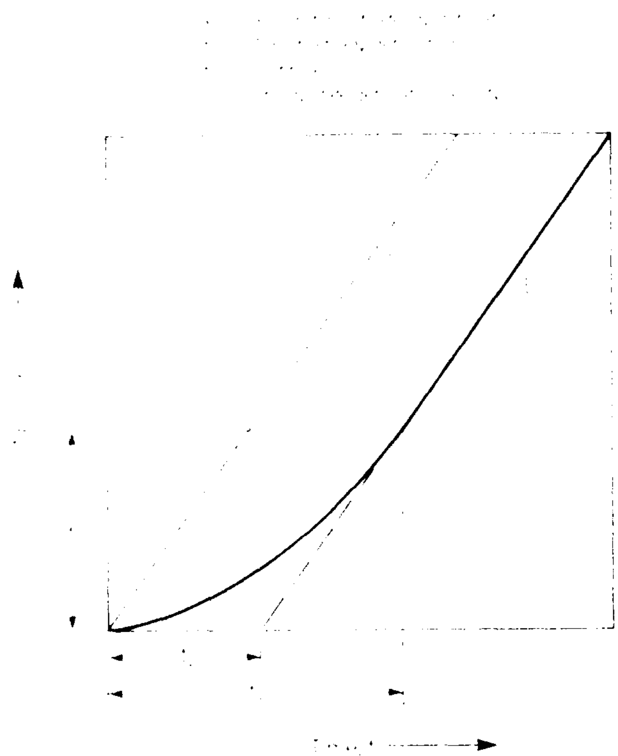

Figure 4: Typical shock initiation space/time plot for a solid explosive showing the parameters used to assess the build-up to detonation process.

Using the data given in Table 3, equation (1) takes the form

$$t_\ell = t_6 - x_6/D \qquad (2)$$

The value for D was taken as 7.54 km/s. Thus in reference to Figures 3 and 4, t_ℓ corresponds to the steady state detonation velocity intercept with the time axis.

3. *Discussion*

The space/time plots in Figure 3 give a qualitative assessment of the variation in detonation build-up for the different types of experimental assemblies. Both the run distances and times can be estimated even though the initial part of the curves are based on limited data. The lost times, however, allow a quantitative measure of the build-up process. Both sets of data show a consistent trend and there are no contradictions.

The data for shots 1 to 3 in Table 4 show that the delay in the build-up to detonation using the normal fuze/booster/explosive filling assembly in Figure 1 is not large but nevertheless significant. Results from the three tests are reasonably reproducible. The prompt onset of detonation for the assembly with no inert material between the CH-6 pellet and Composition B (Shot 4, Table 4) demonstrates that the inert materials have allowed rarefactions and shock attenuation to affect the initiating shock pulse generated by the booster. Inspection of the assembly shows the booster is heavily confined and has a similar thickness and radius. This suggests that the predominant direction of the rarefactions that erode the shock will be from the side of the shock as it traverses the low density inert packing material (glazed board, felt). Also the shock will be attenuated by reflections as it passes through the density discontinuities produced by the glazed board, felt and metal interfaces. The effect of an additional 2 mm gap by the insertion of inert material in the shock path (4 extra glazed boards) is shown by the results from Shot 5. In this test the lost time and run to detonation data increased 3½ to 4 times compared to that for the normal set-up. Note that for Shot 5 the second probe did not function. This was attributed to the shock being too weak to short out the probe

Literature data for the maximum run to detonation distance in Composition B from large booster charges are a few tens of millimetres approaching the failure threshold [3, 4]. It would be expected that the maximum run distance for smaller geometry charges as represented by the boosters used in the tests would be less than these literature values. Consequently the results in Table 4 indicate that the amount of inert material used in the assembly for Shot 5 is close to producing the failure condition. This is only a single result but the trend in the data from the tests is clear. If the data from Shot 5 are indicative then it may be concluded that increasing the distance between the booster and main explosive filling by the inclusion of additional inert material (glazed boards, felt padding) or air gaps could lead to detonation propagation problems.

The additional confinement provided by a full shell assembly may assist the build-up process compared to shots 1 to 3. However, the difference is not expected to be significant since the assembly in Figure 1 does reproduce the more important features of the booster/main charge environment.

Reference to Figure 5 shows that, unlike the shallow intrusion fuze, the booster for the long intrusion type of fuze protrudes deep into the explosive main charge. In this situation initiation would be expected to occur through the side wall of the booster cavity as well as through the end. Table 4 shows that the detonation pressure and therefore the output shock from the CH-6 booster is considerably larger than that from the pressed TNT supplementary booster charge. However the larger geometry of the TNT charge and its greater initiation area would produce a longer duration shock pulse to offset the reduced peak pressure. The effect of these differences in the initiating shock on the build-up process in the main filling cannot be assessed because of the unavailability of data for the long intrusion fuze system.

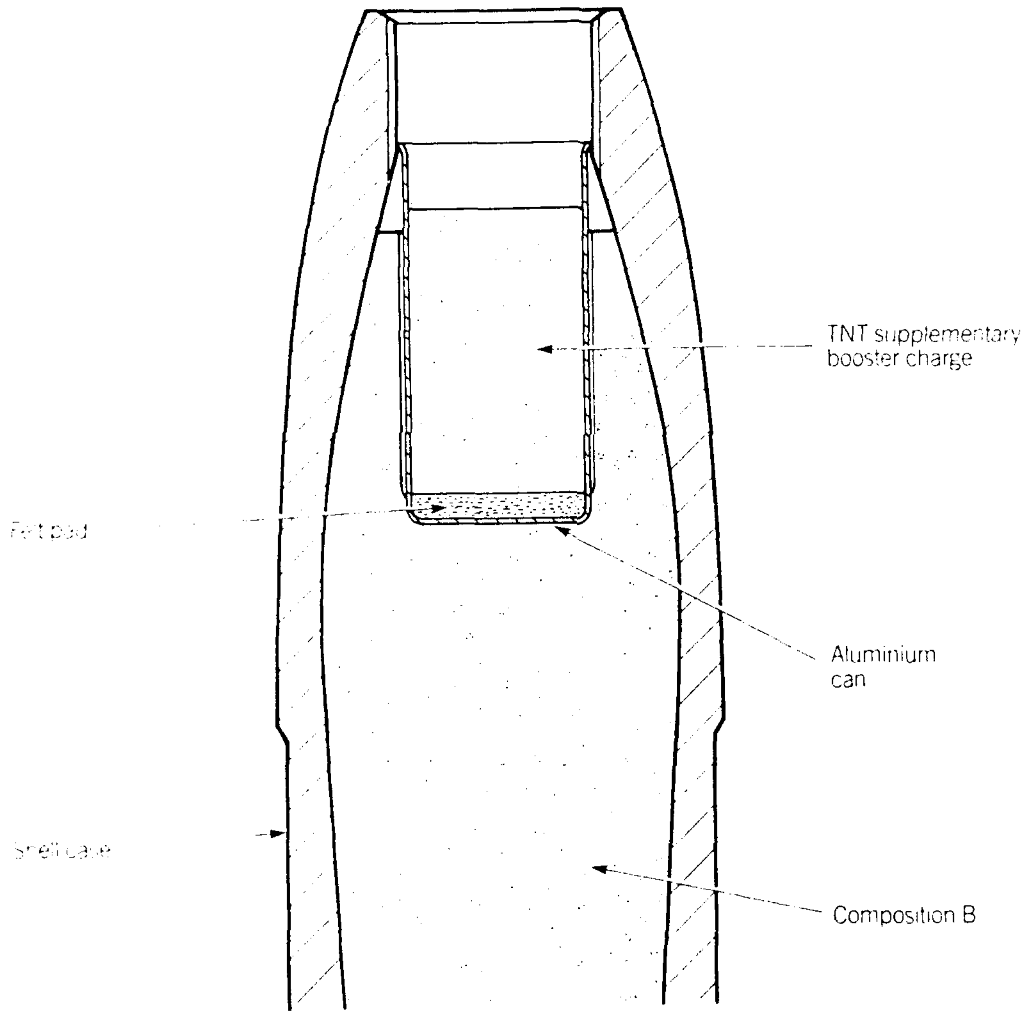

Figure 5: *Sketch showing location of supplementary booster charge in 105 mm HOW HE M1 shell filling.*

4. Conclusions

1. The Composition B samples detonated in all five experiments.

2. Laboratory tests designed to simulate the M732 shallow intrusion fuze assembly in 105 mm HOW HE M1 shell produced a small but significant delay in the build-up to detonation in the Composition B explosive filling.

3. An increased gap of 2 mm (by the addition of extra glazed board packing) between the M732 booster and 105 mm M1 main charge in the test assembly produced a marked increase in the delay to detonation that may have been close to the detonation failure threshold.

5. Recommendations

Consideration should be given to undertaking a more detailed investigation to assess the effect of likely combinations of glazed boards, felt padding and air gaps on the build-up to detonation in the 105 mm M1 shell filling from the M732 fuze booster. For comparison the investigation could include measurements of the build-up to detonation in the same shell filling but using the long intrusion fuze booster system.

6. Acknowledgements

We should like to record our appreciation to Messrs J. Juffs and G. Goodman of EDE for assisting in the supply of the fuze components and advice on the fuze/booster designs and to Messrs M. Wolfson and T. Bussell of MRL for assistance with the tests.

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AUTHOR(S)	CORPORATE AUTHOR
M. Chick and L. McVay	DSTO Materials Research Laboratory PO Box 50 Ascot Vale Victoria 3032

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